

6. HFCs, PFCs, and Sulfur Hexafluoride

U.S. Emissions of HFCs, PFCs, and Sulfur Hexafluoride

Halogenated substances are chemicals that have been engineered for a variety of industrial uses. Some are greenhouse gases with high global warming potentials (GWPs) as compared with carbon dioxide and, therefore, may have an effect on global climate disproportionate to the relatively small volumes emitted.⁴⁹ Emissions of halogenated substances can be classified into two groups according to the accuracy with which their GWPs can be determined.

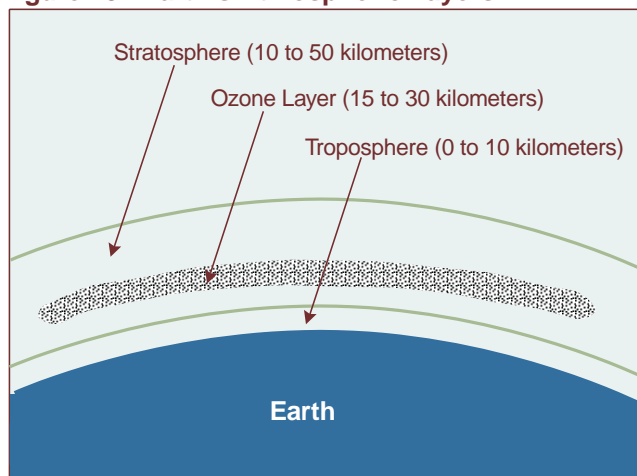
The first group consists of chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and other chlorine-containing gases. These compounds absorb infrared radiation at wavelengths that would not otherwise be absorbed, making them potent greenhouse gases with direct radiative forcing effects hundreds or thousands of times greater than that of carbon dioxide. Because they contain chlorine, however, these substances also tend to destroy the ozone layer, located in the middle to upper stratosphere (Figure 15), which absorbs damaging ultraviolet radiation from the sun. Because ozone is a greenhouse gas, the reaction tends to offset the net warming effects of the chlorine-containing halogens to varying degrees. As a result, their effective GWPs are difficult to determine.

CFC production ceased in January 1996 in accordance with the Copenhagen Amendments to the Montreal Protocol (except for production of CFCs used in metered dose inhalers for asthma patients). In addition, all HCFC production is required to be phased out by 2030. The United Nations Framework Convention on Climate Change (UNFCCC) excludes from its provisions gases covered by the Montreal Protocol and, therefore, does not address CFCs and HCFCs.

The halogenated substances in the second group, which are the focus of this chapter, include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆). These compounds also absorb

infrared radiation that would not otherwise be absorbed in the troposphere, and they have relatively high radiative forcing impacts. In contrast to the chlorine-containing halogenated substances, these compounds do not destroy ozone. Thus, their estimated GWPs, expressed in metric tons carbon dioxide equivalent, can be more accurately evaluated. The Kyoto Protocol to the UNFCCC explicitly lists HFCs, PFCs, and SF₆ as greenhouse gases affected by its provisions.

Figure 15. Earth's Atmospheric Layers



Source: U.S. Environmental Protection Agency.

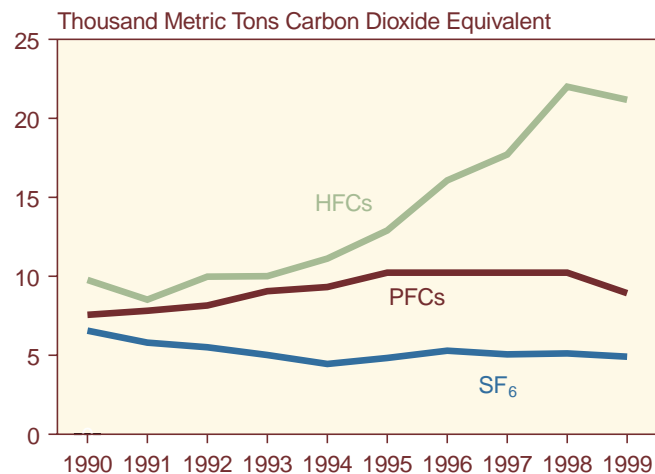
In 1999, U.S. emissions of HFCs, PFCs, and SF₆ were estimated to be 137.9 million metric tons carbon dioxide equivalent, a 57-percent increase over 1990 levels, primarily due to increases in HFC emissions.⁵⁰ Emissions of HFCs, which are used as replacements for CFCs as blowing agents, refrigerants, solvents, and in automobile air conditioners, overall have been growing during the 1990s (Figure 16). In turn, emissions of CFCs are decreasing, according to recent estimates published by the Energy Information Administration.⁵¹ PFCs are emitted as a byproduct of aluminum smelting and are used in semiconductor manufacturing as etchants and cleaning agents. In contrast, emissions of PFCs and SF₆ have remained relatively stable since 1990.

⁴⁹Global warming potentials from Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change* (Cambridge, UK: Cambridge University Press, 1996), p. 121.

⁵⁰Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000), <http://www.eia.doe.gov/oiaf/1605/1605a.html>.

⁵¹Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000), <http://www.eia.doe.gov/oiaf/1605/1605a.html>.

Figure 16. Estimated U.S. Emissions of HFCs, PFCs, and Sulfur Hexafluoride, 1990-1999



Source: Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000), Table 31, p. 64.

Projects Reported

For the 1999 data year, 27 entities reported on 36 projects that reduced emissions of halogenated substances 17-percent increase in the number of entities reporting and a 3-percent increase in the number of projects reported for 1998. In addition to HFCs, PFCs, and SF₆, the 1999 projects included reported reductions of other halogenated substances, including CFCs (CFC-11, CFC-12, and CFC-113) and HCFCs (HCFC-22, HCFC-123, and HCFC-142b).

Nineteen of the entities reporting for 1999 were electric utilities; three were aluminum smelters (Alcan Ingot, Noranda Aluminum, Inc., and VANALCO, Inc.); two were from the chemical and allied products industry (Allergan, Inc. and the Dow Chemical Company); one was from the communications industry (AT&T); one was a local government in New York State (Madison

County Department of Solid Waste & Sanitation); and one was from the holdings and other investment office industry (CLE Resources). Eighteen of the 19 electric utilities participated in the Climate Challenge Program sponsored by the U.S. Department of Energy (DOE). Other voluntary programs with which the projects reported in this category were affiliated include the Climate Wise Recognition Program, the Voluntary Aluminum Industrial Partnership, and the Sulfur Hexafluoride Emissions Reduction Partnership for Electric Power Systems. In addition, all of the 27 entities that reported on projects to reduce emissions of halogenated substances used the long form to report their activities to the Voluntary Reporting Program.

For 1999, emissions avoidance and recycling were the two most frequently reported project types (16 and 15 projects reported, respectively), followed by substitution of other chemicals (9 projects reported). Other types of projects reported for 1999 included the destruction of halogenated substances and the use of improved appliances. No general halogenated substance projects, where the types of activities are not specified, were reported for 1999 (Table 16). Reductions of HFCs, PFCs, and SF₆ emissions were reported for 18 projects, totaling 4,330,829 metric tons carbon dioxide equivalent (Table 17).

Emission Reductions by Gas

In terms of metric tons of native gas (i.e., not weighted for GWP), overall reported project-level reductions of perfluoromethane, perfluoroethane, and SF₆ in 1999 were lower than those reported for 1998 (Table 18), primarily because of the increased use of HCFCs and HFCs as replacements for CFCs. The largest GWP-adjusted reductions were reported for PFCs at 3,691,507 metric tons carbon dioxide equivalent (Table 17). Reported reductions of SF₆ for 1999 dropped by 31,659 metric tons carbon dioxide equivalent (5 percent) but still were triple the value reported for 1995 (Table 18).

Table 16. Number of Projects Reported for Halogenated Substances, Data Years 1994-1999

Project Type	1994	1995	1996	1997	1998	1999
General	1	1	0	1	0	0
Reclamation: Recycling	7	10	10	14	15	15
Reclamation: Destruction	0	0	1	1	0	1
Substitution	2	6	8	7	8	9
Emissions Avoidance	3	6	8	14	17	16
Use of Improved Appliances	0	1	1	1	1	1
Other Projects/Activities	1	1	0	0	0	0
Total Number of Projects	15	22	23	30	35	36

Note: Project totals may not equal sum of components because some projects may be counted in more than one category.
Sources: Energy Information Administration, Forms EIA-1605 and EIA-1605EZ.

Table 17. Reported Reductions of Hydrofluorocarbon, Perfluorocarbon, and Sulfur Hexafluoride Emissions, Data Year 1999

Gas	Emission Reductions Reported	
	Metric Tons of Gas	Metric Tons Carbon Dioxide Equivalent
HFC-134a	-1.3	-1,738 ^a
Perfluoromethane	498.4	3,239,438
Perfluoroethane	49.1	452,070
Sulfur Hexafluoride	26.8	641,058
Reported Total	NA	4,330,827

^aThe negative reduction for HFC-134a represents an increase in emissions due to its use as a substitute for ozone-depleting CFCs and HCFCs that are being phased out under the Montreal Protocol.

NA = not applicable.

Sources: Energy Information Administration, Form EIA-1605 and EIA-1605EZ. Global warming potentials from Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change* (Cambridge, UK: Cambridge University Press, 1996), p. 121.

Table 18. Reported Reductions in Emissions of Halogenated Substances, Data Years 1994-1999
(Metric Tons of Gas)

Gas	1994	1995	1996	1997	1998	1999
Perfluoromethane	465.77	431.00	486.12	482.00	507.00	498.38
Perfluoroethane	45.78	42.50	48.31	58.34	51.64	49.14
HFC-134a	-0.02	-0.03	-0.03	-0.03	-1.34	-1.34
HFC-152a	NR	NR	126.96	0.00	0.00	0.00
Sulfur Hexafluoride	3.76	8.74	-3.15	23.28	28.15	26.82

NR = not reported.

Source: Energy Information Administration, Forms EIA-1605 and EIA-1605EZ.

Hydrofluorocarbons

HFCs are used as replacements for ozone-depleting substances such as CFCs. U.S. emissions of HFCs were estimated at 78 million metric tons carbon dioxide equivalent in 1999, a 117-percent increase over 1990 levels.⁵² HFCs are used to replace CFCs as blowing agents, in automobile air conditioners and refrigerators, and in other manufacturing applications, where emissions result from system leaks. In the semiconductor industry, HFCs are also used in plasma etching and chemical vapor deposition processes. HFC-23 is a byproduct of HCFC-22 manufacturing.

One project reported by UNICOM resulted in a net increase in HFC emissions of 1.3 metric tons, equivalent to 1,738 metric tons of carbon dioxide. UNICOM has operated a central cooling plant serving commercial buildings in Chicago since 1995 that uses the refrigerants HCFC-22 and HFC-134a. The plant has replaced older, leakier equipment in the individual buildings served by the plant resulting in a net reduction in emissions of ozone-depleting refrigerants (CFC-12, CFC-12, and HCFC-22) but an increase in emissions of HFC-134a.

Perfluorocarbons

The principal source of PFC emissions is aluminum smelting. PFCs are produced during aluminum production when the alumina content of the electrolytic bath falls below critical levels required by the electrolytic effect. The resulting electrical upset in the reduction cell is manifested as a rapid voltage increase. The gases formed accumulate at the anode of the reduction cell (hence the name "anode effect"). PFCs are also used in some semiconductor manufacturing processes and, consequently, may be emitted from fabrication plants.

For 1999, three companies (Alcan Ingot, Noranda Aluminum, Inc., and VANALCO, Inc.) claimed reductions in emissions of PFCs totaling 3,691,507 metric tons carbon dioxide equivalent, which accounted for 85 percent of total reported project-level emissions of PFCs, HFCs, and SF₆ in 1999. During 1999, efforts by VANALCO, Inc., and Noranda to reduce PFC emissions were focused on controlling the amount of alumina in solution to avoid anode effects and monitoring the process more closely to stop or correct them expeditiously. Noranda reported the largest individual reductions

⁵²Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000), <http://www.eia.doe.gov/oiaf/1605/1605a.html>.

among the three projects in this category for 1999. According to Noranda's report, perfluoromethane emissions were reduced by 3,165,500 metric tons carbon dioxide equivalent and perfluoroethane emissions by 441,600 metric tons carbon dioxide equivalent in 1999. Alcan Ingot reported that, as a result of its efforts to reduce anode effects, perfluoromethane emissions were reduced by 73,938 metric tons carbon dioxide equivalent and perfluoroethane emissions by 10,470 metric tons carbon dioxide equivalent. VANALCO, Inc., which also reported a project in this category, claimed no PFC reductions for 1999. The U.S. Environmental Protection Agency sponsors the Voluntary Aluminum Industrial Partnership, which seeks to reduce emissions of PFCs, carbon tetrachloride, and SF₆ during primary aluminum processing. For 1999, Alcan Ingot, Noranda, and VANALCO, Inc., all reported participation in the program.

Sulfur Hexafluoride

Sulfur hexafluoride is used as an insulator for circuit breakers, switch gear, and other electrical equipment and as a cover gas in magnesium smelting. It is also emitted during the aluminum smelting process. It has a

very high GWP—23,900 times the warming effect of carbon dioxide per ton emitted. Therefore, even small amounts of SF₆ can play a disproportionate role in U.S. contributions to climate change.⁵³

For 1999, 11 companies, including Allegheny Energy Inc., Baltimore Gas & Electric, and Southern Company, claimed reductions in SF₆ emissions that totaled 641,058 metric tons carbon dioxide equivalent, accounting for 15 percent of the total reported project-level reductions in emissions of PFCs, HFCs, and SF₆.

The Southern Company reported the largest single sulfur hexafluoride emission reduction for 1999 at 413,470 metric tons carbon dioxide equivalent, followed by GPU, Inc., at 72,504 metric tons, Allegheny Energy at 64,395 metric tons, and NiSource/NIPSCO at 40,762 metric tons carbon dioxide equivalent. These four project-level claims of emission reductions combined to account for 93 percent (591,130 metric tons carbon dioxide equivalent) of total reported project-level reductions of SF₆ emissions for 1999 and 14 percent of total project-level emission reductions claimed for HFCs, PFCs, and SF₆ combined (Table 19).

Table 19. Largest Reported Project-Level Reductions of Sulfur Hexafluoride Emissions by Reporter, Data Year 1999

Company	SF ₆ Emission Reductions Reported		Percent of Total Reported Reductions of HFCs, PFCs, and SF ₆
	Metric Tons of Gas	Metric Tons Carbon Dioxide Equivalent	
Southern Company	17.3	413,470	10
GPU, Inc.	3.0	72,504	2
Allegheny Energy, Inc.	2.7	64,395	2
NiSource/NIPSCO	1.7	40,762	1
TXU	0.9	22,441	1
Public Service Enterprise Group	0.5	11,340	<1
Pacific Gas & Electric Company	0.5	10,800	<1
Reported Total	26.6	635,711	15

Note: Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Form EIA-1605.

⁵³Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000), <http://www.eia.doe.gov/oiaf/1605/1605a.html>.